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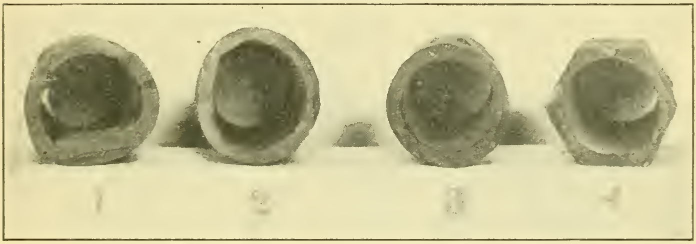
TILE DRAINAGE



Some Good and Bad Shapes of Tile.

BY F. W. TAYLOR

NEW HAMPSHIRE COLLEGE

OF

AGRICULTURE AND THE MECHANIC ARTS

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GENERAL SUMMARY

(1) Pole, slab and stone drains have been superseded by the modern tile drains. The use of tile is becoming more and more extended every year.

(2) The effects of tile drainage are that the surplus water is removed from the soil; the soil is better ventilated; roots are given more room; the soil is made warmer; and the available moisture is increased.

(3) The size of tile will depend upon the fall and the area drained. For mains 4-inch, and for laterals 3-inch will usually be found most satisfactory and economical. In laying drains get all the fall possible.

(4) For clay soils drains should be about two and one half feet deep and 35 to 50 feet apart. For porous, sandy soils they may be three and one half feet deep and 60 to 100 feet apart.

(5) Select the lowest ground for the main. Have as few outlets as possible. Put in laterals through the wettest places first.

(6) If the fall is slight have it accurately determined by a competent surveyor. In other cases the ordinary carpenter's or home-made water level may be used.

(7) Begin digging at the outlet. Make the ditch just wide enough for the man to work in. Be sure the bottom is properly graded so that no low places are left in it.

(8) Round tile,—hard burned, free from lime, straight, smooth on the inside, and with ends square-cut are the best.

(9) Place very hard-burned tile next to the outlet. Use Ys for making all connections of laterals with mains.

(10) In filling the ditch, cover the tile first with loose dirt or sand. The plow may then be used to advantage.

(11) The classes of land in New Hampshire needing drainage are (1) Meadow lands; (2) Gently rolling tillable lands; (3) Lowlands around swamps or lakes; (4) Lowlands adjacent to salt water.

(12) Thorough drainage on most lands will cost $35 to $40 per acre. Many lands can be greatly benefited for $15 or $20 per acre.

TILE DRAINAGE

BY F. W. TAYLOR.

HISTORICAL.

In the early history of underdrainage the drains were made by laying bundles of twigs or brush in the ditch and covering them with ground, the water being expected to trickle through the passageways left. In other cases three or four round poles or two slabs with convex sides laid together were placed in the ditch and covered. Sometimes boards were set on edge in the form of an inverted trough. All of these devices, however, were temporary and were of service only about as long as the wood remained sound. More permanent underdrains were later made by filling the bottom of the ditch with small stones; by setting flat stones on edge in a V-shape; or else by using three or four stones and building a rectangular-shaped waterway. Brick were sometimes used in place of stone, and in some instances blocks of peat were utilized by cutting cylindrical cavities in them. Many of these early stone drains, which were properly made, have lasted a long time and have done good service, but their construction at the present time has been largely superseded by the use of drain tile. It is supposed that pipe tile were first used for drains in France about 1600. About 1800 Mr. Parkes, an Englishman, placed sheets of clay around wooden cylinders and when thoroughly dried drove the wood out. The horseshoe tile were imported into this country in 1835, and the first manufacturing plant was established here in 1838. The use of drain tile was not common until about 1850, and only a comparatively few were used until after the Civil War. At the present time there are over 5,000 factories at work in the United States with an annual output valued at $3,200,000.

EFFECTS OF TILE DRAINAGE.

The first and one of the most obvious effects of drainage is to rid the soil of its surplus water. Plants require a *moist* soil but they cannot grow in a *wet* one. The water which makes a soil moist is that which adheres to the individual soil particles in the shape of a thin film and which completely fills only the smaller spaces between the particles. This kind of soil water is called capillary because it will move through the soil in any direction by what is known as capillary attraction. It is believed that plants must depend entirely upon this kind of water for their supply, and hence its maintenance is of the greatest importance. On the other hand, the water which makes a soil wet fills all the spaces in the soil which are not occupied by the soil particles themselves. This kind of water is called gravitational because it can move in only one direction and that is downwards, through the force of gravity. Plants cannot grow until this surplus gravitational water has been removed. The "freezing out" or heaving of winter grain and posts on clay soils is not occasioned by the low temperature but by the formation of ice in the upper part of the soil, which causes an expansion and a consequent upward movement in the direction of least resistance. If the soil is drained the water will pass off and the injury and trouble on account of freezing will be largely avoided.

Soils are better ventilated by drainage. The roots of plants require air just as do the parts above ground. When nearly all the spaces in the soil are filled with water, very little air can exist there. When we remember, too, that it is only from the air which finds its way into the soil that the bacteria, which live in leguminous plants, can get their nitrogen, we see again the importance of thorough ventilation. Drainage helps to ventilate a soil in several different ways: (1) The soil drys out deeper and in so doing shrinkage cracks are formed, through which the air will readily pass; (2) the lines of tile themselves form passageways or chimneys through which the air is forced with every change in atmospheric pressure; (3) after a heavy rain the air in the soil is forced out by the water and, as this passes off through the drains, a fresh supply of air is drawn in behind it.

A third effect of drainage is to increase the room which the roots may occupy. Most of our cultivated plants will naturally send their roots down three to four feet in the soil. If the gravitational water has not been removed to this depth, the roots will be forced to make a shallow growth and will be unable to utilize the full resources of the soil. Drainage will so lower the ground water that roots may penetrate to their normal depth.

Another very important effect of drainage is that the soil is made warmer. We know that evaporation is a cooling process, as is illustrated by the wet and dry bulb thermometer. When the surplus water in the soil during the early spring can be removed downwards through the drains instead of upwards through evaporation at the surface, the temperature of the soil is maintained considerably higher. Besides this, the water which falls as rain during the early summer is always warmer than the soil and if it can be absorbed and allowed to percolate down to the drains the soil will be somewhat warmed. Experiments have shown that the surface foot of a soil well drained is five or six degrees warmer than the same soil undrained. This difference in temperature will very materially hasten the germination of seeds and the length of the growing season will thus be increased. Not only in this way is the growing season lengthened but a drained soil can always be worked a few days earlier in the spring and can be cultivated sooner after every heavy rain than an undrained one. The matter of a few days in the length of the season is a very important consideration for New England conditions, as it frequently means the success or failure with many crops.

A fifth and very important effect of drainage is to increase the available soil moisture. On first thought one would say that the amount of soil moisture would be lessened, but let us see. When a plant must grow in a soil which contains a surplus of water nearly to the surface, it is forced to develop a shallow root system because the roots cannot penetrate where all the spaces are filled with water. The moisture in this shallow zone of root growth will soon be used up and the soil become dry. This layer of dry soil will then retard the capillary rise of water from below and the plant will suffer in consequence. On the other hand, if the soil is drained and the surplus water is lowered the roots can develop deeper and thus have a larger area from which to draw their moisture. Besides this, a drained soil partakes of the nature of a sponge and will the more readily absorb and hold the water which falls as rain in a condition available for the plants.

SIZE OF TILE AND FALL OF DRAINS.

The size of the main drain will depend upon its fall and the area which it drains. The greater the fall the smaller may be the tile. If the fall is doubled the carrying capacity is increased about one third. A four-inch main will suffice for most ordinary systems where not more than ten or twelve acres are to be drained. If twenty or thirty acres are to be drained into one main it should be five or six inches in diameter. Tile larger than necessary should not be used, as the cost increases much faster proportionally than the size of the tile; for example: Three-inch tile may be listed at $25, four-inch at $45, five-inch at $75 and six-inch at $100 per thousand.

For laterals a three-inch tile will usually be found most satisfactory, as it is large enough to carry off in a reasonable time all the surplus water of our heaviest rains. The danger in using smaller tile lies in the fact that it does not take a great deal of sediment to fill them, and unless they are laid on a perfectly true grade with a good fall their efficiency will soon be diminished. A variation of an inch below a true grade will result in filling a two-inch tile just half full of sediment, while an inch of sediment in a three-inch tile will only reduce its carrying capacity about one fourth. Last fall we dug up some two-inch tile laid ten years ago in a fine clay soil with only a slight fall, which had become almost full of sediment and were practically useless. It is pretty difficult to determine the proper size of tile unless the detailed conditions under which they are to be laid are known. Errors resulting from too small tile are most serious in their effects and the only safe plan is to be sure they are large enough even though the first cost is somewhat greater.

In regard to the fall of drains, it may be said that the best rule is to have all the fall possible. A foot to the hundred feet is desirable if it can be had. Cases will sometimes occur where three inches or even less must be accepted and in these instances the bottom of the ditch must be carefully leveled and graded so that no sags will occur. It is important, also, to have a uniform fall, that is, not to change from one grade to another in the same line of tile. In changing from a steep to a less steep grade the velocity of the water is checked and there is danger of sediment being deposited where the change is made. Of course there is no objection to changing from a small grade to a greater one for in this case the velocity will be increased and the sediment will be the better carried onward.

DEPTH AND DISTANCE APART OF DRAINS.

The depth at which drains should be placed will depend largely upon two conditions: First, the nature of the soil and, second, the average distance of the ground water below the surface. Commonly speaking, four feet is considered deep drainage, three feet medium and two to two and one half feet shallow. In heavy, retentive clay soils it is advisable to lay the tiles between medium and shallow for two reasons: First, because the water filters through them so slowly that it takes a long time to reach the drains, and, second, because the cost of digging increases very rapidly with the depth in a hard clay soil. In a more porous, loamy soil experience has shown that the most practical depth is about three feet. The second condition mentioned above, which affects the depth, is important in this respect, in that the level of the ground water changes with the season and is usually highest in the spring. If the ground water then comes too near the surface only in the spring and naturally lowers itself later on in the season it may be desirable to lay the drains only deep enough to dry the land for plowing and cultivation at the proper time. Shallow drainage will usually suffice where this condition of affairs is to be met. On the other hand, when the ground water is not sufficiently low at any season of the year for the maximum development of the roots, it is best to resort to deep drainage, and unless the soil is a retentive clay the tiles may be placed from three and one half to four feet deep.

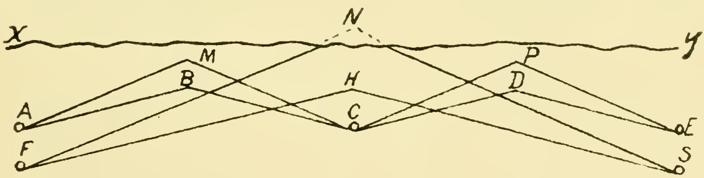


FIG. 1. Showing effect of soil and depth of drains on distance apart. Line XY indicates surface of ground. Line ABCDE indicates surface of ground water in porous soil with tile 2 feet deep and 50 feet apart. Line FHS indicates the same for tile 3 feet deep and 100 feet apart, the ground water having the same slope and coming equally near the surface in both cases. Line AMCPE indicates surface of ground water in retentive clay soil with tile 2 feet deep and 50 feet apart, while line FNS indicates the same for tile 3 feet deep and 100 feet apart, the slope of the ground water being the same in both cases, but coming clear to the surface of the ground in the latter case.

There is a close relation between the depth and distance apart of drains. The distance apart will depend upon the depth. From Figure 1 it will be seen in order to keep the ground water lowered a certain distance below the surface between lines of tile that the deeper the tile are placed, the further they may be apart. The distance apart is also dependent upon the texture of the soil through which the water has to filter. In a close textured soil, composed of very fine particles, such as our clay soils are, the resistance to the flow is very great, and as a result the ground water surface will have a steeper slope and will rise rapidly back from the drain. Here, then, unless the lines of tile are placed near together or else at a good depth, the ground water will come clear to the surface or very near it, and the drains will not be doing efficient work. This matter is also illustrated in Figure 1. As before noted, tiles should not be placed deep in a fine clay soil, so the only remaining thing to do is to place them in lines close together. Concerning some lines of tile which were laid about sixty feet apart in a heavy clay soil here on the Station farm several years ago, it was noticed that about midway between them no appreciable effects of the drains could be seen, while for a distance of fifteen or twenty feet on either side of them the ground was noticeably drier. Practical experience and observation has shown that from thirty to forty feet is the proper distance for thorough drainage in clay soils. In more open and porous soils, which will admit of the tiles being placed deeper and at the same time allow the water to filter more readily through them, general field practice dictates a distance of fifty to one hundred feet.

LAYING OUT DRAINS.

The first thing to do in laying out a system of drains is to decide on the location of the outlet or outlets. This should always be at the lowest available point, so as to secure the greatest amount of fall. Just as few outlets should be had as possible, as they are always a source of trouble. Next locate the main, having it follow the line and direction of the lowest lying ground. This can be done by noticing the channel in which the greatest amount of surface water tends to run after a heavy rain. The main will thus be likely to have a location somewhere near the center of the area drained rather than on one side of it.

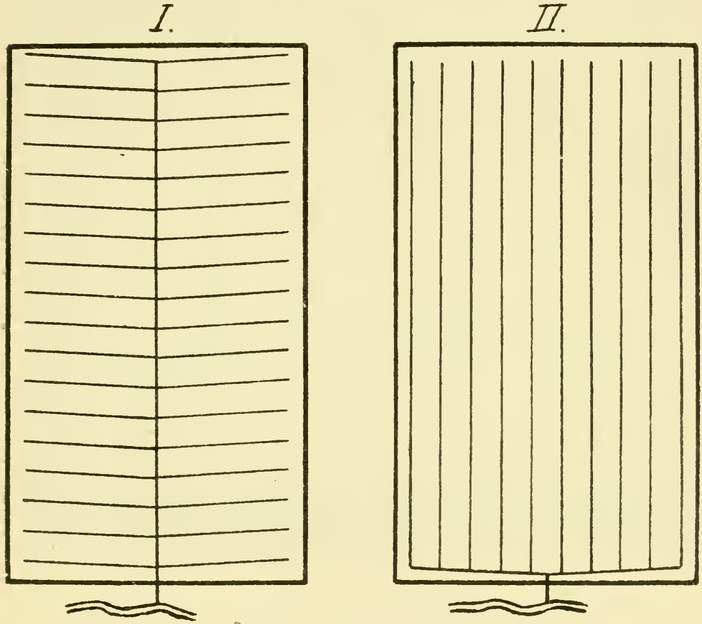


FIG. 2. Two different arrangements of drains.

Of course, when this is done, the laterals entering from both sides drain a certain amount of ground already drained by the main, but as the main in this case is supposed to be in the lowest ground most needing drainage, the extra amount does no harm. On a comparatively flat piece of ground, where there are no particularly low-lying channels, it is better to locate the main at one end or side and place the laterals in parallel lines at nearly right angles to it. These two arrangements are illustrated in

Figure 2. In I 875 feet of four-inch main and 8,100 feet of three-inch laterals are required to drain ten and one third acres with the lines fifty feet apart. In II the same total length of drains are required as in I, but only 475 feet of four-inch main is used. There is thus a saving of about $6.50 in the cost of tile and equally as good drainage obtained. It is seldom that any particular arrangement can be used entirely, as so much depends upon the slope and conformation of the land. It is always important, however, that some systematic arrangement of the drains is made, for thorough drainage in a haphazard way is difficult to obtain and is most expensive. Careful study of the land should first be made and then the drains laid out so as to secure the greatest fall, the least expense for tile, the minimum amount of digging and the most perfect drainage. If at all possible lay all the lines of tile parallel, putting them in through the wettest places first. Then, if your faith and your purse are not strong enough to do thorough work in the beginning you will have your field in such shape that additional lines can be added in the future as your faith and money increases. Another important matter is to keep an accurate plan or plot of the drains on paper. This will show their exact location and will be valuable for future reference, especially if the land should come into the possession of other parties.

DETERMINING THE FALL.

After the main and laterals have been located, with the aid perhaps of a preliminary leveling in case the area is quite flat, their location is marked by stakes driven into the ground every fifty feet, with their tops left four or five inches above the surface. The next step is to determine the total fall of the main. This is done by finding the difference in level between the outlet and the upper end of the main. The leveling can be best done with a surveyor's level and where the grades are slight and require careful work it is usually safest and most economical to hire a competent surveyor to do the job. Where the fall is ample and less accurate work is required, a home-made water level or an ordinary carpenter's level, set on a straight-edge, may be made to answer the purpose. These instruments are illustrated in the cut following. When the total fall, either of the main or laterals, is not quite as great as

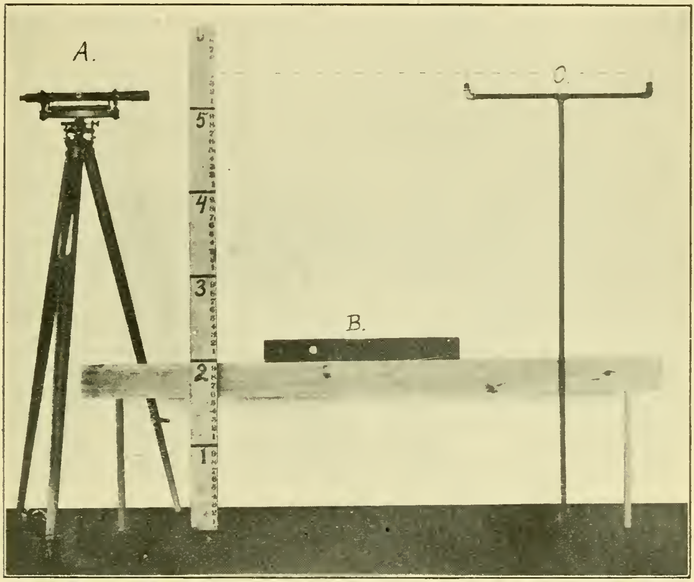


FIG. 3. Different kinds of levels for determining grades. A, surveyor's level; B, carpenter's level; C, home-made water level. The water level is made of half-inch gas pipe, with an upright five feet long and a cross piece two feet long with elbows on the ends. Corks are put in the elbows and pieces of glass tube inserted in the corks. The top of the upright is then stopped and the cross piece filled with water so that it comes up in the glass tubes. The instrument is used by standing it in the ground and sighting along the water level in the two tubes to the rod. When being carried from one place to another the ends of the tubes must be stopped to keep the water in.

is desired, it may be increased by making the drains a little shallower at the upper ends. After the total available fall has been determined, divide it by the number of fifty-foot spaces which the line contains; this, then, will give the fall from one stake to the next. For example, suppose the line was 800 feet long and the total fall was three feet; the 800 feet would give 16 fifty-foot spaces, and the three feet divided by 16 would give 2¼ inches, which would be the fall between the stakes. If the surface of the ground was perfectly level and uniform, the matter of finding the depth to dig the ditch at each stake would be simple enough. In practice, however, we never find land in this condition. To find these various depths we must first secure readings at the different stakes. To do this place the instrument, whether the carpenter's, home-made or surveyor's level, at some point slightly higher than the highest stake and where all the stakes can be seen. Have a man stand a rod marked off into feet and inches or preferably into feet and tenths of feet on top of the first stake. Sight along the instrument and find what height on the rod is on a level with it. Without changing the height of the instrument, point it at all the stakes in any one line and take the readings on the rod. From these readings and the fall from one stake to another, previously determined, the depth of the ditch is calculated.

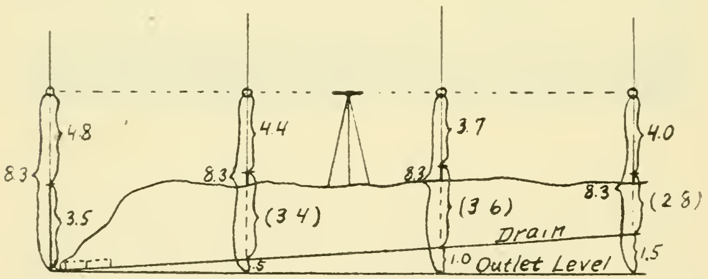


Fig. 4. Showing method of finding depth of ditch.

From the above diagram it will be noticed that the readings are as follows: outlet, 4.8 feet; first stake, 4.4 feet; second stake, 3.7 feet; third stake, 4.0 feet. The outlet reading, plus the height of the outlet stake, equals 8.3 feet, which is the difference in level between the instrument and the outlet. The fall in this case, we will say, has been found to be one foot in 100 or .5 of a foot in 50. If the ditch was to be dug to the same level at the first stake as at the outlet, the depth would be found by subtracting the reading, 4.4 feet, from 8.3 feet. But since the fall of the drain is to be .5 feet from the first stake to the outlet, the depth will be .5 feet less than the difference between 8.3 and 4.4. From the second stake to the outlet the fall is to be one foot, so the depth of the ditch will be one foot less than the difference between the reading, 3.7 feet, and 8.3 feet, which gives 3.6 feet. In the same manner the depth at each stake is found by taking the sum of the reading and the fall to the outlet from the height of the instrument above the level of the outlet. After the depth to which the ditch is to be dug at the various stakes has been determined, it is plainly marked on each stake for the guidance of the digger.

DIGGING THE DITCH.

When the stakes are first set they should be placed in line so that the ditch will be straight. The digging should begin at the outlet and a line should be stretched from one stake to the next to aid in marking out the ditch. It is best to dig the ditch about six inches to one side of the line of stakes, so that there will be no danger of them being broken off or caving into the ditch. A plow can sometimes be used to advantage in opening the ditch, but care must be taken that the grade stakes are not disturbed. In Figure 5 are shown some of the hand tools used for making drainage ditches. No. 1 is the common short-handled shovel, which can be used to throw out a considerable part of the dirt and sometimes all of it. No. 2 has a handle six feet long and is used for grooving the bottom of the ditch for round tile. No. 3 is a heavy spade for use in soft ground. No. 4 is a long-handled tool for grooving the bottom for six-sided tile. No. 5 is a bottoming spade for digging near the bottom of the ditch where a narrow width is wanted. No. 6 is a flat spade with a four-foot handle for throwing out the loose dirt in the bottom of the ditch. No. 7 is a long-bladed spade which can be used in place of No. 2 for making the groove in the bottom. No. 8 is a tile hook for laying the tile from the top of the ground. Although all of these tools are convenient for the purposes intended, their use is not absolutely essential. Many good drains have been put in with no other

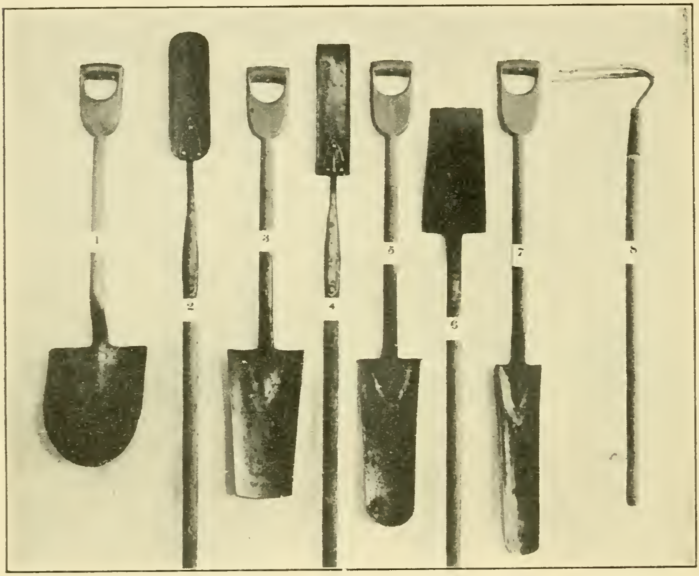


FIG. 5. Showing different kinds of drainage tools.

tool than the common shovel. If the diggers are accustomed to them the work will be facilitated by their use, but if they are not, it is better to allow them to use the tools to their own liking in preference to those theoretically the best. Difficulty was experienced with the two Italians who put in the drains on the Station farm last fall in getting them to use these tools. They would say that they could not work fast with them and, observation proving the fact, they were allowed to use the common shovel for most of the work.

It is important in digging to make the ditch just wide enough for the workman to stand in it, the width being gradually narrowed towards the bottom. New hands must be watched in this respect or they will be throwing out more dirt than is necessary, thus uselessly increasing the cost of digging. For a ditch three feet deep a width of 14 inches at the top and 8 inches at the bottom is

FIG. 6. Getting depth of ditch.

FIG. 7. Laying the tile.

ample. At each stake the digger gets the proper depth of the ditch by measuring down the distance marked on the stake, as is illustrated in Figure 6. After the proper depth at each stake has been secured, the next thing is to grade the bottom of the ditch between the stakes so as to make the fall uniform. This is one of the most important pieces of work in the whole operation, for, if any high or low places occur, the efficiency of the drain will be diminished or perhaps entirely lost. Bringing the ditch to grade is of special importance when the total amount of fall is slight.

If the "boss" ditcher has been careful not much extra work will be required in getting the grade. It may be gotten by stretching a tight line from the top of one stake to the top of the next and measuring down from this at intervals of 15 or 20 feet, or more easily and usually as accurately by placing the eye as near the bottom of the ditch as possible and sighting along, noting the places that are too high and those that are too low. When the grade is finished, take the grooving tool and slide it along to make a little channel in which to lay the tile so that they will remain in place.

KIND OF TILE.

A good drain tile should be hard-burned, giving a sharp ring when struck. It was formerly thought that tile should be soft and porous, so that the water could freely enter them, but Mr. W. I. Chamberlain, in his "Tile Drainage," page 75, cites some very interesting experiments which seem to prove that the porosity of a tile has nothing to do with the water entering it. There is plenty of space at the joints for all the water to enter the tiles. Besides this, a soft-burned tile is very susceptible to the effects of frost and will soon begin to flake and crumble, as is illustrated in Nos. 3 and 4 of Figure 8. It was found by crushing some hard and soft-burned tile that the former would withstand an average weight of 2,600 pounds, while the latter would give way under an average weight of 1,100 pounds. Tile are sometimes made from clay containing pebbles of limestone. These pebbles on burning are converted into quick lime and as soon as water reaches them will begin to slake and the chances are that the tile will crumble. Tile, with lumps of limestone embedded in them, are illustrated in Nos. 1 and 2 of Figure 8 and all these should be discarded before laying. A good tile should be smooth on the inside, straight and with the ends cut off square. It should also be truly circular or hexagonal, depending on which shape is used, so that the ends will fit closely together and prevent the washing in of sand and silt. Nos. 1 and 2 of the illustration on the cover page show two badly formed tiles, while 3 and 4 are almost perfect.

In regard to the shape of tile there is a difference of opinion. Makers of the six and eight-sided tiles claim that they will lie in place better than the round. If the bottom of the ditch is grooved, however, there is little chance for the round tile to get out of place. One ad-

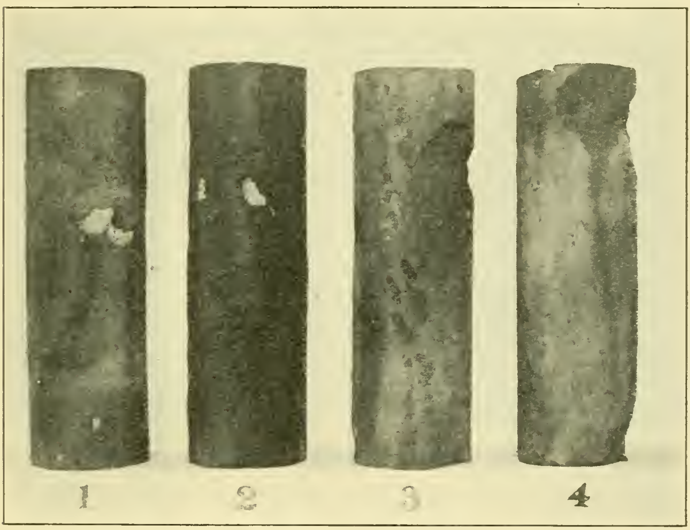


FIG. 8. Showing lime pebbles and effects of frost on tile.

vantage of the round tile is that if the ends do not fit closely in one position it can be turned around any distance until a close fit is obtained. Another point to be considered in favor of the round tile is its greater strength. In making a tile six-sided, the thickness of the walls is reduced nearly one half at the center of each side so that its strength is proportionately diminished. As the result of some crushing trials with round and six-sided tiles selected with as nearly the same hardness as possible, it was found that the hexagonal tiles would break under an average weight of 1,325 pounds, while the round would support 2,360 pounds. The workmen were asked which kind they preferred to lay and, without giving any particular reason, said that they liked the round best.

LAYING THE TILE.

The laying should begin with the main at the outlet. The first eight or ten feet should be very hard-burned tile, or, better yet, glazed sewer pipe, which are not injured by freezing. The outlet should then be walled up with stone to prevent washing or sliding down of the dirt and an iron grating or rods placed over it to keep out burrowing animals. A very well constructed outlet is shown in Figure 9. The laying of the tile should follow soon after the digging, as the sides of the ditch are likely to keep caving in more or less. The tile are laid in the main until the first lateral is reached; five or six of the lateral are then put in and connected to the main with a Y. Either a Y or a T, but preferably a Y, should always be used in making connections, and the purchaser should be sure to order enough and a few extra for every connection to be made. The main is then continued until the next lateral is reached, connected and started, and so on to the third, until the whole is completed; the main is now ready for filling and the laterals for laying. In practice we have found that better and more satisfactory work can be done by laying the tile by hand than with a tile hook. Although somewhat faster work can be done with the hook, the tile cannot be as securely and tightly placed. Figure 7 shows the man in the ditch laying the tile by hand. It is sometimes recommended to place pieces of heavy paper, cloth or sod over the joints or covering the tile with coarse sand to prevent the washing of dirt into the drain. These precautions are all very good and in some cases may be necessary, but in general practice where the tiles are placed tightly together the extra expense of hauling sand and providing several thousand pieces of paper or cloth, besides the trouble of laying them on the joints, will not usually be found profitable. The upper ends of all lines of tile, however, should be carefully closed by placing a flat stone or piece of brick against them.

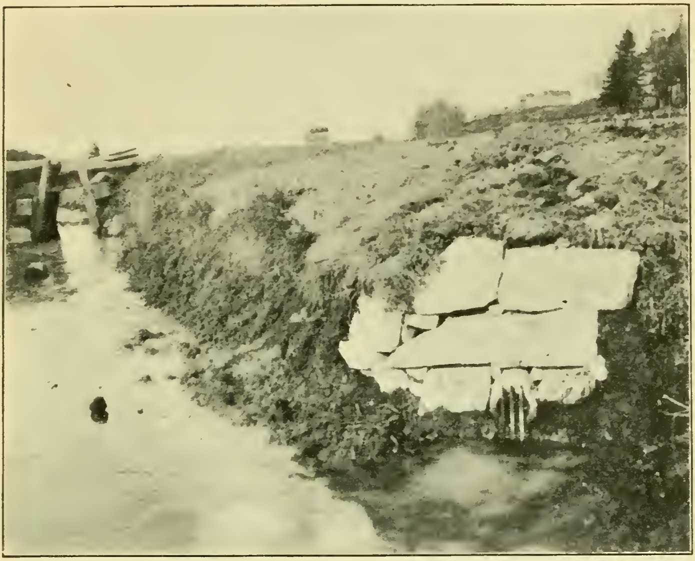


Fig. 9. Showing walled outlet with guards.

FILLING THE DITCH.

The tile should first be covered with loose earth, care being taken that clods and stones are not dropped directly on them and thus break or knock them out of place. After the tile are once covered the remaining dirt may be put back in several ways, the faster the better. Among the hand tools used for this work the short handled shovel is perhaps the best, although with some kinds of dirt the ordinary four-pronged potato hook is very good. There are no horse-power implements made purposely for filling ditches, but several forms of home-made ones can be fixed up. A good scraper can be made by setting a plank on edge and fastening a tongue to it at an acute angle and putting on handles behind. By drawing this along the ditch the dirt is forced sideways into it. A similar scraper may be used for pulling the dirt straight into the ditch with the horses on the opposite side, backing the team when the dirt drops in. The large four-wheeled road scrapers may also be adjusted to do good work. The ordinary plow with an eight-foot double tree can be used very effectively. By turning two or three furrows into the ditch it can usually be filled level full. It does not do as smooth work as the scrapers and some hand finishing must be done afterwards.

To find the comparative expense of filling by hand and with the plow, 80 rods of ditch two and one-half feet deep were taken with the following results:

By hand:	
40 rods, one man, 12¾ hours, at cost of . .	$1.91
With plow:	
40 rods, two men with team, 22 minutes, at cost of	.18
Finishing by hand, 7¾ hours, at cost of . .	1.16
Total	$1.34
Difference	.57

The above figures show that the ditch could be filled about one and one half cents cheaper per rod when the plow and team were used than when all the work was done by hand. Filling with the plow is illustrated in Figure 10. In finishing the ditch all the dirt that was thrown out should be piled up on it and rounded over so that it is eight or ten inches above the level. If this is not done a furrow will be left on top of the drain after the dirt has settled.

CLASSES OF LAND IN NEW HAMPSHIRE THAT WOULD BE BENEFITED BY DRAINAGE.

It may be said in general that all lands where the natural drainage is poor or in which the ground water is less than three feet below the surface at planting time will be benefited by tile drainage. There are a large number of tracts of land in this state varying from a few acres to several hundred which come under the above conditions. These lands may be classified as follows:

(1) Meadow lands.

(2) Gently rolling tillable lands.

(3) Wet lands around inland lakes and along rivers.

(4) Swampy lands adjacent to salt water but above high tide.

Fig. 10. Filling ditches with plow.

"Meadow lands" would include those that are comparatively flat and level and are usually overflowed in the spring, a small brook commonly running through them or at one side. They are used largely for hay and pasture, the cultivated grasses being grown, but in early and dry seasons may be plowed and cultivated. The soil is usually a heavy, dark colored clay with a marked tendency to crack open on the surface when drying out. This clay consists mainly of very fine sand and silt and being of glacial origin is known as "boulder clay." It is a very retentive soil and when dry becomes hard and cloddy. There is usually sufficient fall in these lands to admit of good drainage; the drains, however, should be placed shallow and near together.

The second class of lands comprises those that lie too high to be overflowed and are usually more or less rolling. On these the boulder clay, instead of coming to the surface as in the preceding class, is covered with a mantle of brownish loam ten to twenty inches in thickness. These lands, where not too stony or in forest, are ordinarily cultivated. The clay coming so near the surface, however, causes them to dry out very slowly in the spring and makes the planting season that much later. There will ordinarily be no trouble in securing plenty of fall and good outlets on these lands, and the drains may be placed at a medium depth and about fifty feet apart.

In the third class we have those lands that are quite level and flat and are so wet during the greater part of the year that only wild grasses can be grown on them. The soil is dark colored and frequently quite black, owing to the large amount of organic matter in it. It is usually lighter in texture than the so-called meadow lands, being considerably more sandy and porous. Its origin is also different, having been formed from the gradual accumulation of organic matter and the material carried by streams. The fall on these lands is likely to be slight, but the drains may be placed fairly deep and far apart. When well drained they will be found in the course of several years to be productive for both cultivated crops and grasses.

The fourth class of lands are found only in a limited extent in New Hampshire, being confined to the coast section. They are more or less sandy and have been formed in a way similar to those in the preceding class, except that in this case the material has been deposited by waves and tides. The natural vegetation of these lands is largely swale, bunch and other inferior varieties of grasses. Their drainage in most cases would not be a difficult proposition and would result in a largely increased and varied production of crops as is illustrated by similar lands further south. The tide lands, of course, must be handled by a system of dykes and open ditches instead of tile drains, but for the lands a few feet above tide tile drainage would prove a profitable investment.

The clearing of stones from land is a long and expensive piece of business, and if the farmers of New Hampshire

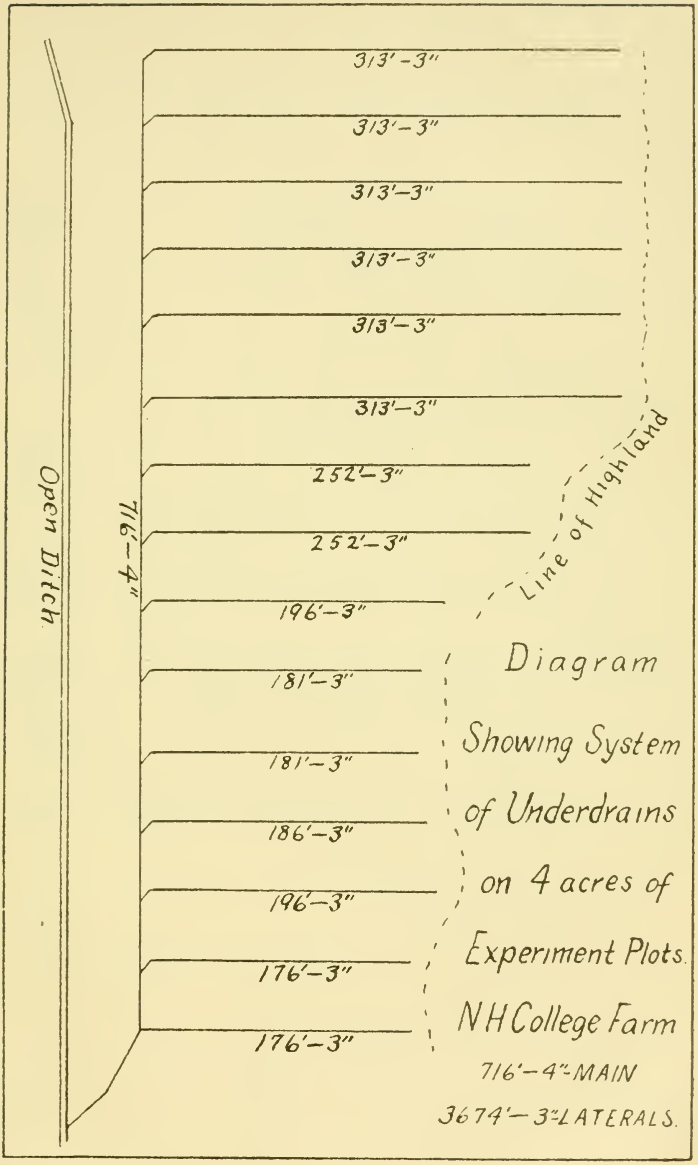
FIG. 11. Filling the ditch by hand.

could have in the bank all the money that has been expended in this way they would be considered rich. Many lands have been wisely and greatly improved by the removal of stones, while many other lands naturally more fertile have not been improved because poor drainage was the drawback. Is it not time then that some steps in another direction be taken? Instead of trying to remove the stones from our rocky fields and pastures, let us look to our meadows and other low lands and try the work of drainage on them. An improvement will be sure to result and the chances are that it will cost less and be more permanent than the carting off of tons of stone.

DRAINAGE SYSTEM PUT IN AT NEW HAMPSHIRE STATION.

During the fall of 1904 four acres of land were laid off into one-tenth and one-twentieth acre plots for experiment purposes. These plots were twenty feet wide with a two-foot alleyway between them. Between every other plot a line of tile was laid, making the lines 44 feet apart. The land was a heavy, sticky clay or clay loam, and came under the preceding classification of "meadow." A diagram showing the arrangement of these drains is given on page 43. It will be noticed from the diagram that instead of running the laterals straight through to the open ditch a main was put in 44 feet from the ditch and running parallel with it, into which the laterals emptied. By this system the same length of tile and amount of digging was required, and instead of having fifteen separate outlets to construct only one was made.

The cost of drainage, which has not been hitherto mentioned, is an important consideration. The cost will depend largely upon three things: (1) cost of tile, (2) cost of digging, (3) distance apart of drains. The cost of the tile will vary with the distance from the factory. Nearly all the New England dealers handle Western made tile. Three-inch tile at the factory cost from $10 to $12 per thousand, but by the time the freightage and dealer's commissions are added, the New Hampshire farmer must pay from $20 to $25 per thousand. The cost of digging will depend upon the nature of the ground and the skill of the ditcher. Ditches in ground that can be thrown out with a shovel without the use of a pick can be dug for half the cost when the pick must be used. Workmen, too, who are accustomed to ditching and who have a certain natural skill, will do the work cheaper than those unskilled. The further apart the drains the less cost is evident.


313'-3"
313'-3"
313'-3"
313'-3"
313'-3"
313'-3"
252'-3"
252'-3"
196'-3"
181'-3"
181'-3"
186'-3"
196'-3"
176'-3"
176'-3"
Open Ditch
716'-4"
Line of Highland
Diagram
Showing System
of Underdrains
on 4 acres of
Experiment Plots.
N H College Farm
716'-4"-MAIN
3674'-3"-LATERALS.

The following itemized account of the cost of labor and materials to thoroughly drain four acres of land here at the Station will be of interest in showing about what the New Hampshire farmer may expect to pay for similar work:

Tile:	
3,674 feet 3-inch at $20 per thousand	$73.48
716 feet 4-inch at $36 per thousand	25.78
15 3 x 4 Ys at $0.20 each	3.00
Unloading tile from cars	6.50
Total for tile	$108.76
Laying out drains and distributing tile:	
Staking and getting levels on field,	
Man with instrument, 6 hours	$3.00
One assistant, 6 hours	.90
Distributing 4,390 feet of tile along ditches,	
Man and team, 11 hours	3.85
Total laying out and distributing	$7.75
Digging:	
Digging ditch, 52 days, 6 hours, at $1.50	$78.90
Grading bottom of ditch, 21 hours, at $0.15	3.15
Total digging	$82.05
Laying and filling:	
Laying tile and just covering, 17.5 hours at $0.15	$2.62
Filling ditch, 8.5 days at $1.50	12.75
Total laying and filling	$15.37
Total cost of drains	213.93

	Cost per rod.	Per cent. of total cost.
Tile	$0.409	50.9
Laying out drains and distributing tile	.029	3.6
Digging	.308	38.3
Laying and filling	.058	7.2
Total per rod	$0.804	100.0

It will be seen from the above that the cost of the tile delivered on the ground is just about half the total cost in this section. The cost of the digging was 38 per cent., although it may be said that this is higher than can usually be counted on. The digging was done by unskilled workmen and at a season when the ground was so hard and dry that every shovelful, after the first eight inches had been thrown out, had to be picked loose. If the work had been done in the spring the cost of the digging would have been reduced at least one third. The average depth of the ditches was two and one half feet, although for a distance of about 400 feet they had to be dug between three and four feet to bring them to grade. The fall of the main was six inches to the hundred feet, while the average for the laterals was about ten inches.

The total cost in this case has been $53 per acre, which may be considered about the maximum for ordinary work. It must be remembered that here the lines of tile were placed close together, and that the cost represented is that for "thorough drainage." It is estimated that most lands of the state could be thoroughly underdrained for between $35 and $40 per acre, while many of them could be greatly improved by putting in a single line or two at an expenditure of $15 or $20 for each acre benefited. Drainage is a permanent improvement, and although its first cost seems high its effects are timely and far reaching.

PUBLICATIONS OF EXPERIMENT STATION.

The following publications of the Station are available for distribution:

No. 2. Feeding Experiments.
No. 3. When to Cut Corn for Ensilage.
No. 4. The Science and Practice of Stock-Feeding.
No. 5. Fertilizers and Fertilizing Materials.
No. 6. Experiments with Fertilizers.
No. 7. Test of Dairy Apparatus.
No. 8. Feeding Experiments. Part 1. Principles of Feeding. Part 2. Corn Meal, Middlings, Shorts, and Cotton-Seed Compared.
No. 11. Pig Feeding. Part 1. Results of Feeding Skim Milk and Corn Meal versus Corn Meal and Middlings. Part 2. Digestion Experiment.
No. 12. Fertilizer Experiments.
No. 14. Ensilage in Dairy Farming.
No. 16. Effect of Food on Composition of Butter Fat.
No. 17. Stock Feeders' Guide.
No. 18. Effect of Food on Milk.
No. 19. Spraying Apples and Pears against Fungi.
No. 20. Effect of Food on Milk. Feeding with Fats.
No. 21. Farmyard Manures and Artificial Fertilizers.
No. 22. Prevention of Potato Blight.
No. 23. Some Dangerous Fruit Insects.
No. 24. The Flow of Maple Sap.
No. 25. The Composition of Maple Sap.
No. 26. Analysis of Fertilizers and Wood Ashes.
No. 27. Spraying Experiments in 1894.
No. 28. Remedies for the Horn Fly.
No. 29. Remedies for Flea Beetles.
No. 30. An Experiment in Road Making.
No. 31. Seventh Annual Report. 1895.
No. 32. Studies of Maple Sap.
No. 33. Two Shade-Tree Pests.
No. 34. Surface and Sub-Irrigation out of Doors.
No. 35. The Codling Moth and the Apple Maggot.

No. 36. Analyses of three Common Insecticides.
No. 37. Crimson Clover.
No. 38. The Tent Caterpillar.
No. 39. The Army Worm.
No. 40. Eighth Annual Report. 1896.
No. 41. Potatoes: Varieties, Fertilizers, Scab.
No. 42. Part 1. Tomato Growing in New Hampshire. Part 2. Notes on Tomato Breeding.
No. 44. The Cankerworm.
No. 45. Fruit and Potato Diseases.
No. 46. Part 1. An Experiment with a Steam Drill. Part 2. Methods of Road Maintenance.
No. 48. Ninth Annual Report. 1897.
No. 53. The Farm Water Supply.
No. 56. Poisonous Properties of Wild Cherry Leaves.
No. 57. Forage and Root Crops.
No. 58. Cost of Raising Calves.
No. 59. Tenth Annual Report. 1898.
No. 60. Green Corn under Glass.
No. 61. Inspection of Fertilizers in 1898.
No. 62. Forcing Pole Beans under Glass.
No. 64. The Forest Tent Caterpillar.
No. 66. Experiments in Pig Feeding.
No. 67. The Spiny Elm Caterpillar.
No. 68. Eleventh Annual Report. 1899.
No. 69. Inspection of Fertilizers in 1898.
No. 70. Experiments with Muskmelons.
No. 71. Corn Culture.
No. 72. Insect Record for 1899.
No. 74. Growing Strawberries in New England.
No. 75. The Forest Tent Caterpillar. Second Report.
No. 76. Utilizing the Greenhouse in Summer.
No. 77. Experiments in Road Surfacing.
No. 78. Bovine Tuberculosis.
No. 79. Twelfth Annual Report. 1900.
No. 80. Inspection of Fertilizers in 1900.
No. 81. Insect Record for 1900.
No. 82. Feeding Farm Horses.
No. 83. Value of Meadow Muck.
No. 84. Forcing Dwarf Tomatoes.
No. 85. Remedies for the Cankerworm.
No. 86. Growing Watermelons in the North. Classification of Watermelons.
No. 87. Thirteenth Annual Report. 1901.

No. 88. Inspection of Fertilizers, 1901, Analyses of Ashes, etc.
No. 89. The Squash Bug.
No. 90. Insect Record for 1901.
No. 91. Killing Woodchucks with Carbon Bisulphide.
No. 92. Silage Studies.
No. 93. The Cold Storage of Apples.
No. 94. Remedies for Fleas.
No. 95. How to Grow a Forest from Seed.
No. 96. Fourteenth Annual Report. 1902.
No. 97. Inspection of Fertilizers. 1902.
No. 98. Inspection of Feeding-Stuffs. 1902.
No. 99. Selected List of Vegetables for the Garden.
No. 100. White-Fly of Greenhouses.
No. 101. Fungous Diseases and Spraying.
No. 102. Insect Record. 1902.
No. 103. Standard Milk.
No. 104. Fifteenth Annual Report. 1903.
No. 105. Fruit Growing. Varieties for N. H.
No. 106. Forestry.
No. 107. Brown-Tail Moth.
No. 108. Inspection of Fertilizers.
No. 109. San Jose Scale.
No. 110. Orchard Management in New England.
No. 111. Experiments with Potatoes and Potato Culture.
No. 112. Remedies for the Black Fly.
No. 113. Experiments in Pig Feeding.
No. 114. The Babcock Test for N. H. Dairymen.
No. 115. Sixteenth Annual Report. 1904.
No. 116. Inspection of Feeding Stuffs. 1904.
No. 117. Inspection of Fertilizers. 1904.